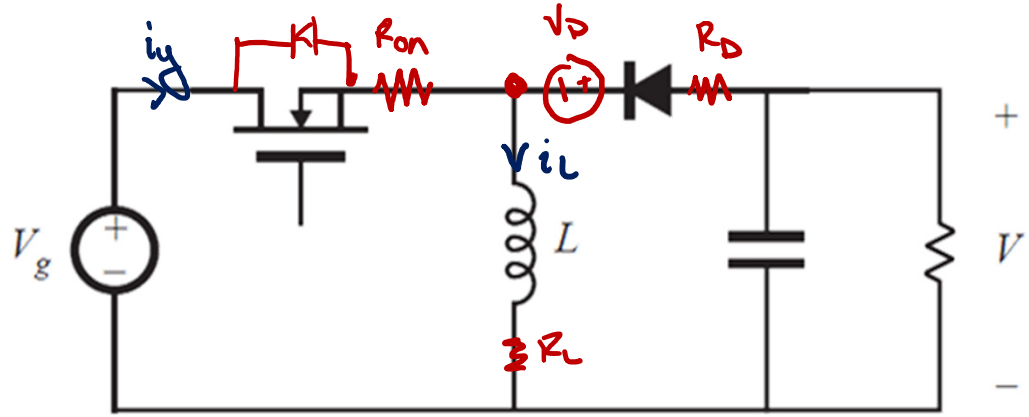
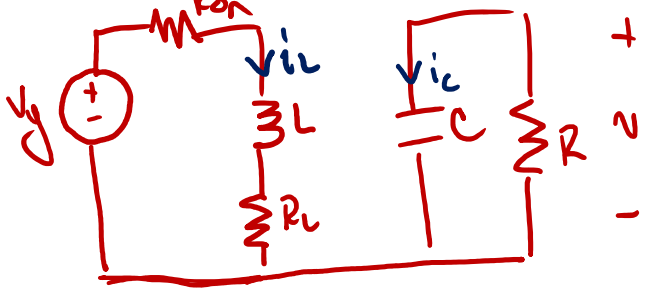
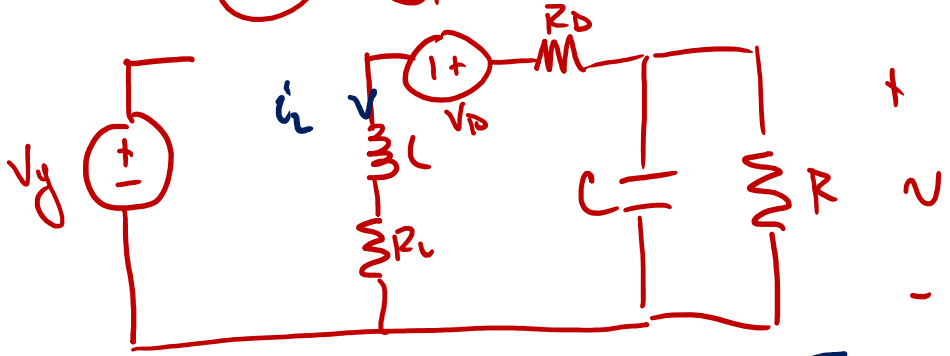
Buck-Boost Converter with Nonideal Semiconductors



① MOSFET ON



② Diode ON



$$\langle v_L \rangle|_{T_s} = 0 = D\left[V_g - I_L R_{on} - I_L R_L\right] + D'\left[V - I_L R_L - I_L R_D - V_D\right]$$

$$0 = DV_g + D'V - DI_L R_{on} - D'I_L R_D - D'V_D - I_L R_L$$

$$\langle i_c \rangle|_{T_s} = 0 = -\frac{V}{R} - D'I_L$$

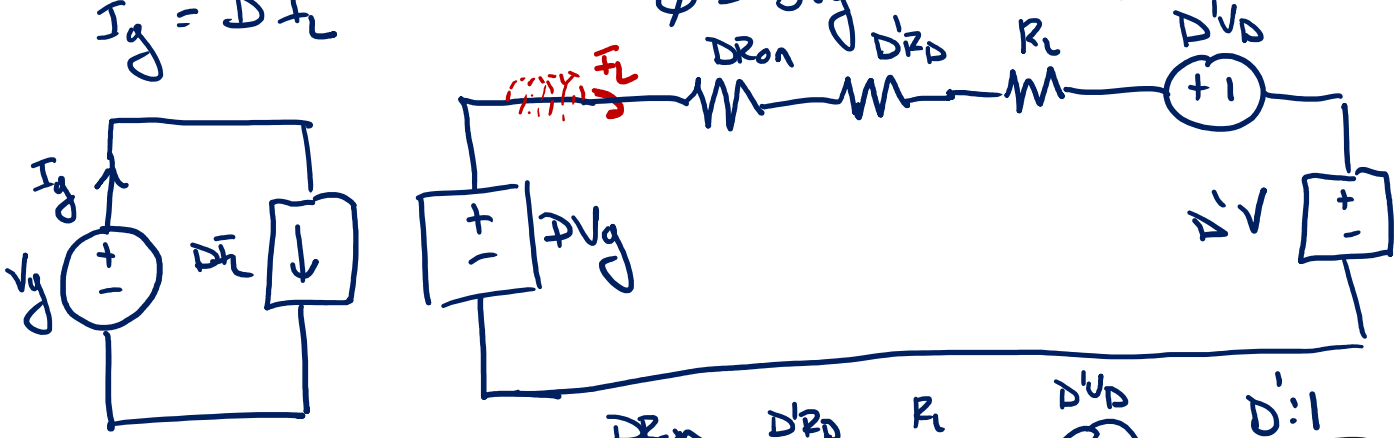
$$\langle i_g \rangle|_{T_s} = DI_L = I_g$$

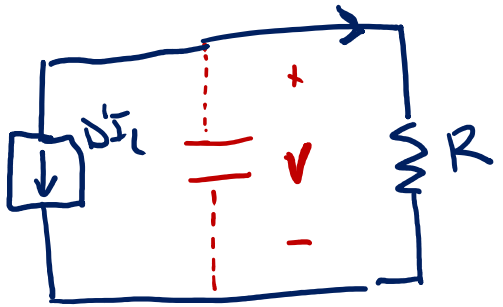
Equivalent Circuit Model

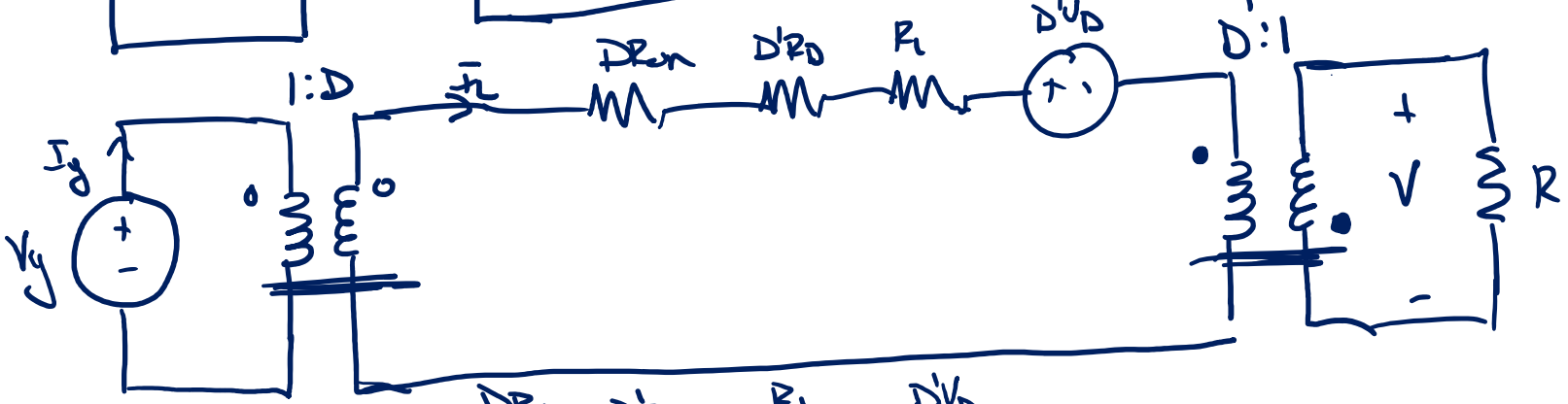
$$I_g = D I_L$$

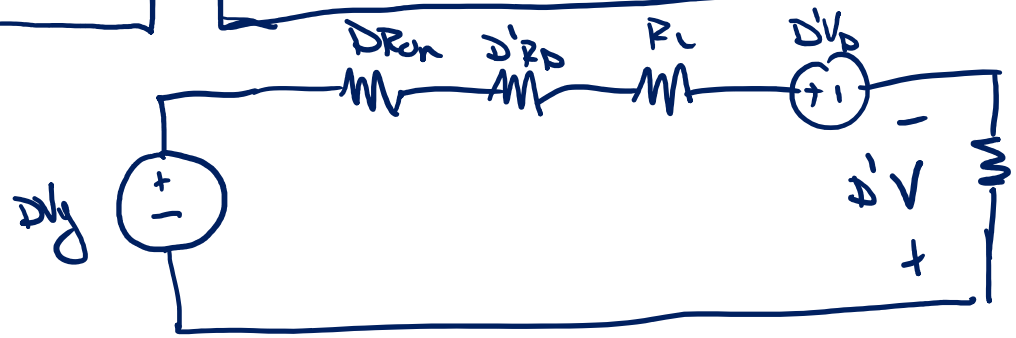
$$\phi = DV_g + D'V - DI_L R_{on} - D'I_L R_D - D'V_D - I_L R_L$$

$$\phi = -\frac{V}{R} - D'I_L$$









$$-D'V = (DV_g - D'V_D)\frac{D'^2R}{D'^2R + DR_{on} + D'R_D + R_L}$$

Circuit Solution

$$M = \frac{V}{V_g} = \frac{1}{D'}\left(D - \frac{D'\frac{V_D}{V_g}}{}\right) \frac{D'^2 R}{D'^2 R + DR_{on} + D'R_D + R_L}$$

$$M = \left(\frac{D}{D'}\right)\left(1 - \frac{D'}{D}\frac{V_D}{V_g}\right) \frac{D'^2 R}{D'^2 R + DR_{on} + D'R_D + R_L}$$

$\left(\frac{D}{D'}\right)$ → Mideal

$\left(1 - \frac{D'}{D}\frac{V_D}{V_g}\right)$ → η

$\frac{D'}{D}\frac{V_D}{V_g} \rightarrow \frac{V_D}{\frac{D}{D'}V_g} \approx \frac{V_D}{V}$ → % drop in η due to diode V_D

Average Losses in diode V_D are $\frac{1}{T_s}\int_0^{T_s} V_D \cdot i_D \, dt = \frac{1}{T_s} V_D \int_0^{T_s} i_D \, dt = V_D \langle i_D \rangle_{T_s} = V_D I_D$

Average Losses in a restance R_x are $\frac{1}{T_s}\int_0^{T_s} v_R \cdot i_R \, dt = \frac{1}{T_s}\int_0^{T_s} (i_R \cdot R)\, i_R \, dt = R\frac{1}{T_s}\int_0^{T_s} i_D^2 \, dt$

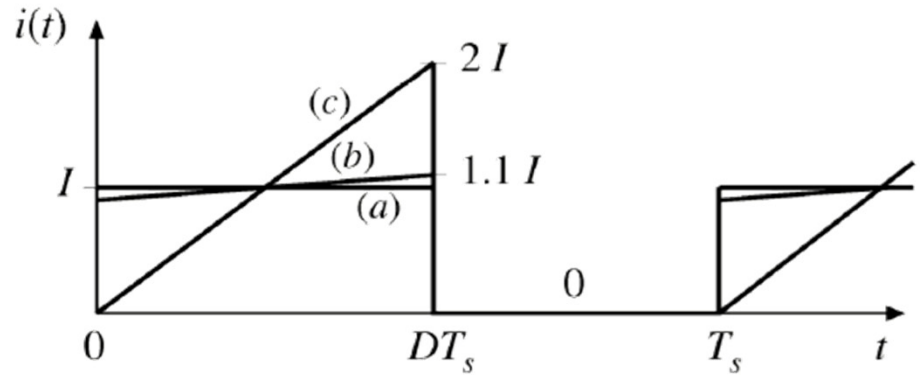
$= R\, i_{Rms}^2$

But, we are using $P_R = I_{R,DC}^2 R$ ✗

Average vs RMS Currents

- Model uses average currents and voltages
- To correctly predict power loss in a resistor, use rms values
- Result is the same, provided ripple is small

MOSFET current waveforms, for various ripple magnitudes:



Inductor current ripple	*MOSFET rms current*	*Average power loss in* R_{on}
(a) $\Delta i = 0$	$I\sqrt{D}$	$D\,I^2\,R_{on}$
(b) $\Delta i = 0.1\,I$	$(1.00167)\,I\sqrt{D}$	$(1.0033)\,D\,I^2\,R_{on}$
(c) $\Delta i = I$	$(1.155)\,I\sqrt{D}$	$(1.3333)\,D\,I^2\,R_{on}$

0.3% error in P_R

33% error in P_R

Chapter 4

SWITCH REALIZATION

Implementing with SPST Switches

Step 1: Implement circuit w/ only SPST switches

Use passive sign convention to look at each SPST switch

Now we have additional switching states possible

A on, B off → (1)

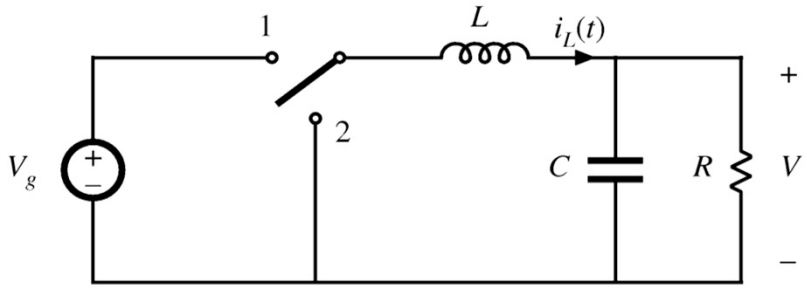
A off, B on → (2)

A off, B off → dead time

A on, B on → Very Bad "shoot-through"

Buck converter

with SPDT switch:



with two SPST switches: